Peter Baker, P.Eng.

Windows and Water Leakage Testing

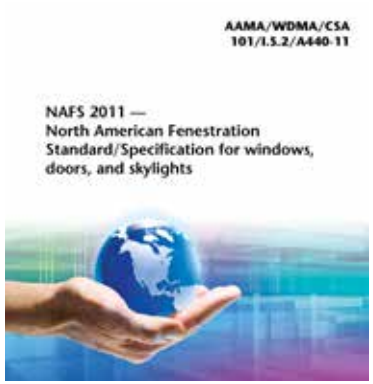
BSC Experts Session 2014

Building Science Corporation

Overview

- Window Classifications
- Laboratory Test Standards
- Specifying Windows and Testing
- Field Performance Testing
- Window/Door Failures
- Window/Door Details (residential)
- Window/Door Details (commercial)

Window Classification



Window Classification

- AAMA 101
  - Performance Class
    - R: commonly used in one- and two-family dwellings.
    - LC: commonly used in low-rise and mid-rise multi-family dwellings and other buildings where larger sizes and higher loading requirements are expected.
    - CW: commonly used in low-rise and mid-rise buildings where larger sizes, higher loading requirements, limits on deflection, and heavy use are expected.
    - AW: commonly used in high-rise and mid-rise buildings to meet increased loading requirements and limits on deflections, and in buildings where frequent and extreme use of the fenestration product is expected.

Window Classification

- AAMA 101
  - Performance Grade
    - Operating force (if applicable)
    - Air leakage resistance
    - Water penetration resistance
    - Uniform load deflection test
    - Uniform load structural test
    - Forced-entry resistance (if applicable)

Window Classification

Casement Window:
Class R — PG25: Size tested 760 × 1520 mm (~30 × 60 in)
Class R — PG25: Size tested 29.9 × 59.8 in
Class R — PG1200 (SI): Size tested 760 × 1520 mm

For all designators, there is an option to add the product type at the end of the designator at the manufacturer's discretion.

Examples:
Class R — PG25: Size tested 760 × 1520 mm (~30 × 60 in) — Casement
or
Class R — PG25: Size tested 760 × 1520 mm (~30 × 60 in) — Type C

Legend:

Class R	— Performance Class (see Clauses 0.2.1 and 4.4.2.3)
PG25	— Performance Grade (PG) (IP) (see Clauses 0.2.3 and 4.4.2.4)
PG1200 (SI)	— Performance Grade (PG) (SI) (see Clauses 0.2.3 and 4.4.2.4)
Size tested 760 × 1520 mm	— maximum size tested (SI) (see Clause 4.4.2.5)
Size tested 29.92 × 59.84 in	— maximum size tested (IP) (see Clause 4.4.2.5)
Casement or Type C	— product type (see Clause 4.4.2.2)

Window Classification

- Performance Grade (PG)
  - PG "number" is a function of the following tests and based on specific design pressures (DP).
    - Water penetration resistance (ASTM E547 and ASTM E331)
    - Uniform load deflection test (ASTM E330)
  - Other tests with minimum performance are also required (more associated with performance class than grade)
  - The DP ratings can be used as a secondary designator

Window Classification

- Design Pressure (DP)
  - Water penetration resistance (ASTM E547 and ASTM E331)
    - Tested at 15% of the DP for R, LC, CW
    - Tested at 20% of the DP for AW
  - Uniform load deflection test (ASTM E330)
    - Tested at 150% of the DP
    - Permanent deformation:
      - 0.4% of the span for R and LC
      - 0.3% of the span for CW
      - 0.2% of the span for AW

Window Classification

Table 6.5
Gateway requirements
(See Clauses 0.2.5.1, 4.3.2.2, 4.4.2.3, 4.4.3.2, 4.4.3.3, 4.4.3.4, 6, 6.4.2, 6.4.4, 9.3.4.2, and 9.3.4.3 and Table 0.1.)

Performance Class	Minimum Performance Grade (PG)	Minimum design pressure (DP) Pa	(–psf)	Minimum structural test pressure (STP) Pa	(–psf)	Minimum water penetration resistance test pressure Pa	(–psf)
R	15	720	(15.04)	1080	(22.56)	140	(2.92)
LC	25	1200	(25.06)	1800	(37.59)	180	(3.76)
CW	30	1440	(30.08)	2160	(45.11)	220	(4.59)
AW	40	1920	(40.10)	2880	(60.15)	390	(8.15)

Note: *The IP equivalents identified are for approximate reference only and do not in any way imply accuracy of the measurement or the equipment. See Clause 1.3. Precision and bias statements are provided in the applicable test methods referenced in this Standard/Specification.*

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Window Classification

Totally Clear?

Just wait, it gets better….

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Laboratory Test

Designation: E 331 – 00

Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference[1]

Designation: E 547 – 00

Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference[1]

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Laboratory Test

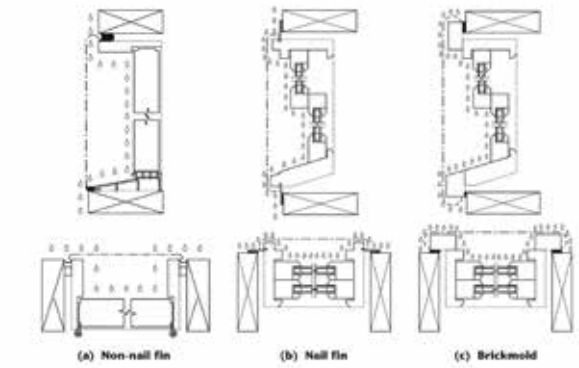

Figure 9.2 of AAMA 101-11

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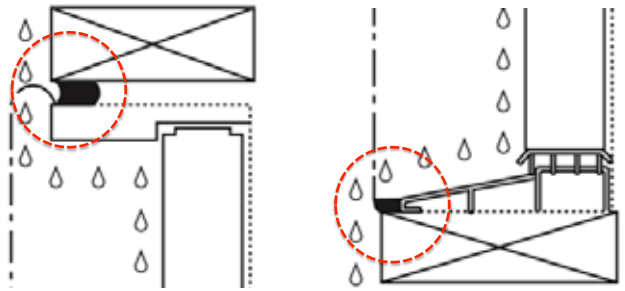
Laboratory Test



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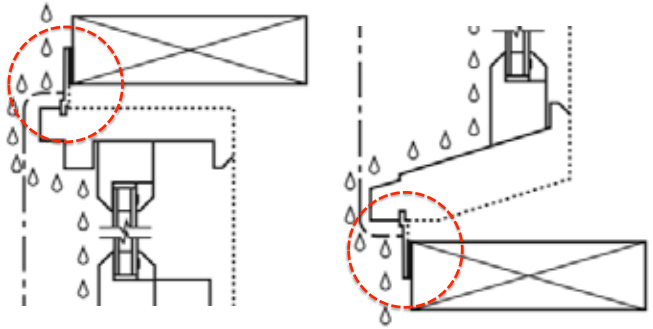

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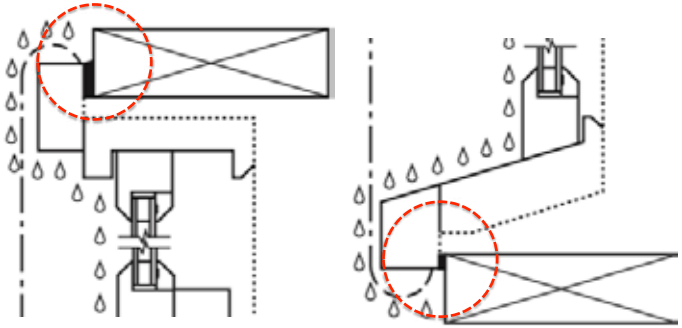

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Laboratory Test

- Laboratory testing completed under face sealed installation
- Real construction is often not face sealed
  - Residential windows are often flanged windows typically installed in pan flashed and drained opening
  - Commercial glazing can be any number of configurations
- Field tests may or may not be completed under face sealed conditions

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Laboratory Test

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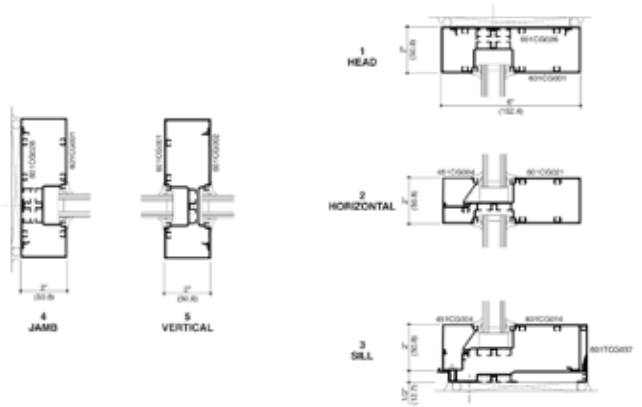
Laboratory Test



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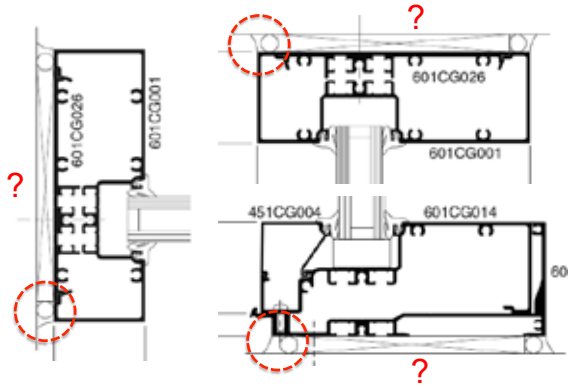

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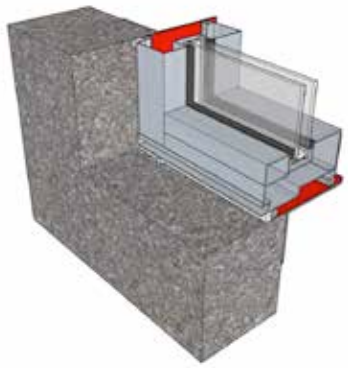

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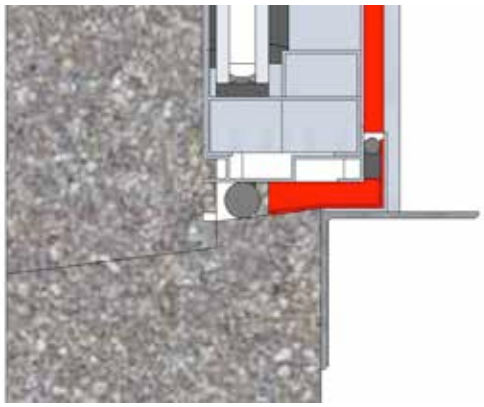

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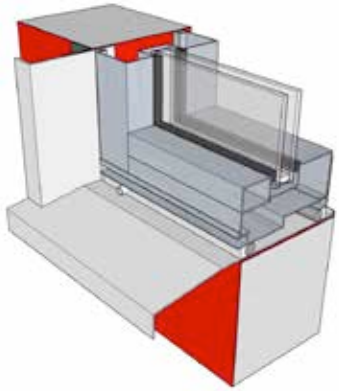

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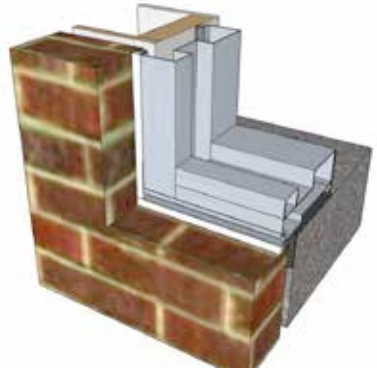

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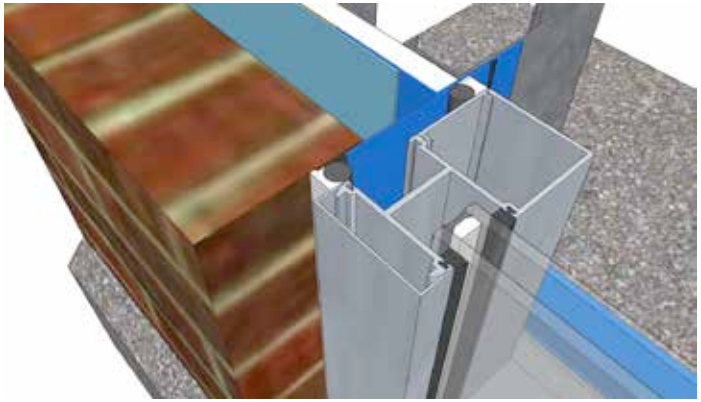

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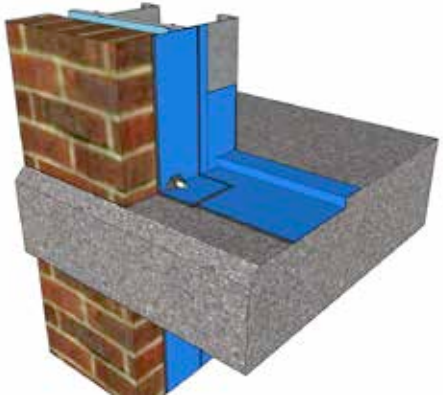

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Laboratory Test

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Laboratory Test

END RANT

Laboratory Test

- Failure Criteria

3.2.3 *water penetration*, *n*—penetration of water beyond a plane parallel to the glazing (the vertical plane) intersecting the innermost projection of the test specimen, not including interior trim and hardware, under the specified conditions of air pressure difference across the specimen. For products with non-planer glazing surfaces (domes, vaults, pyramids, etc.) the plane defining water penetration is the plane defined by the innermost edges of the unit frame.

Laboratory Test

- Failure Criteria

"So… you're telling me a window can leak and pass?"

Window Specifications

DIVISION 08 - OPENINGS

08 11 13	Hollow Metal Doors and Frames
08 14 16	Flush Wood Doors
08 31 13	Access Doors and Frames
08 32 13	Sliding Interior Wood Doors
08 32 14	Sliding Aluminum Framed Glass Doors
08 32 15	Sliding Interior Glass Doors
08 33 24	High Speed Overhead Coiling Doors
08 36 13	Sectional Doors
08 41 13	Aluminum-Framed Entrances
08 41 14	Aluminum-Framed Storefronts
08 41 26	All-Glass Entrances and Storefronts
08 42 13	Aluminum-Framed Terrace Doors
08 44 23	Structural-Sealant-Glazed Curtain Walls
08 45 11	Translucent Linear Channel Glazing System
08 51 16	Aluminum Windows

It just got better….

Window Specifications

- Water Infiltration Specifications
  - Performance Grade?
  - Design Pressure?
  - Building Pressure?
  - Minimum Pressure?

Window Specifications

- Specifying a Performance Class of window sets minimum gateway requirements
- Specifying a Performance Grade builds off the minimum gateway requirements
- Specifying a Minimum DP should also be considerate of the building cladding loads
- Specifying a Minimum Test Pressure should at least meet the PG or DP for the PC…..???

Window Specifications

- What if you don't know what you want?

  …Go with the building loads.

Typically specify a water infiltration resistance test pressure equal to 20% of the largest positive wind design load.

Window Specifications

- Sample Text

"Product shall not exhibit water infiltration when tested in accordance with ASTM E547 (and/or ASTM E331) when tested at a test pressure equal to or greater than 20% of the maximum positive wind design pressure for the project"

Window Specifications

- Sample Text
  (with Performance Grade Designation)

"Product shall not exhibit water infiltration when tested in accordance with ASTM E547 (and ASTM E331) when tested at a test pressure consistent with the minimum specified DP for the Performance Class of the product as defined in Section XXX, or 20% of the maximum positive wind design pressure for the project, whichever is greater"

Window Specifications

- Product Performance Specifications are NOT the same as Field Verification Performance Specifications
- Products should be field tested to the wind design pressure of the project.
- Field Tests are typically done at 2/3rd (0.667) the specified laboratory test pressure

Window Specifications

- Sample Text

"Field water infiltration performance verification shall be performed at 20% of the maximum positive wind design pressure for the project multiplied by 0.667, but not less than 1.9psf (4.18psf) following guidelines set out in AAMA 502-11 (or AAMA 503-08)

Field Testing

Field Testing

- *AAMA 502-11 Voluntary Specification for Field Testing of Newly Installed Fenestration Products*
- *AAMA 503-08 Voluntary Specification for Field Testing of Newly Installed Storefronts, Curtain Walls and Sloped Glazing Systems*
- These documents both reference *ASTM E1105 Standard Test Method for Field Determination of Water Penetration*

Field Testing

- *ASTM E1105 Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform or Cyclic Static Air Pressure Difference*
- This is a test of the window system, and not the window to wall interface
- We often use this test to evaluate both
- Is this a reasonable test?

Field Testing

- *ASTM E1105*
  - 15 minute static test or 5 minute cyclical test (4 cycles)
  - Specified water test pressure x 0.677
  - Water delivery at 5.0 gal/ft2.hr
- Let's look at this…

Field Testing

- Assume DP50 window
  - 50psf x 15% x 0.677 = 5.0psf or 0.96in of water
  - 5.0psf is roughly equivalent to 45mph wind
  - 5.0gal/ft2.hr is roughly equivalent to 8.0in of rainfall per hour
    - From E1105 the greatest recorded rainfall in the contiguous United States is 5.0in
  - These conditions are maintained for 15minutes or for four 5 minute cycles with a 1 minute break in between
- Aggressive test and not necessarily indicative of the in-field performance of the assemblies
- Good test to check potential pathways

Field Testing

- How much testing?
  - Punched windows and doors - test 1% to 2% of the total number of units installed
  - 500 windows = 5 to 10 test
  - 5 to 10 test @ 2 to 3 tests a day
  - 2 to 5 days of testing

Field Testing

- How much testing?
  - Storefronts and Ribbon windows - 1 test for every 2,500ft2 to 5,000ft2 installed
  - Assume test chamber is 5'x5' to 7'x7' (25ft2 to 50ft2)
  - 2,500ft2 to 5,000ft2 divided by 25ft2 to 50ft2
  - 1% to 2%

Field Testing

- How much testing?
  - Curtain Wall systems - 1 test for every 5,000ft2 to 10,000ft2 installed
  - Assume test chamber is 7'x7' to 10'x10' (50ft2 to 100ft2)
  - 5,000ft2 to 10,000ft2 divided by 50ft2 to 100ft2
  - 1% to 2%

Field Testing

- How much testing?

This should be indicated in the project specifications

Field Testing

- Mock Up Testing
  - In Situ
    - Should be scheduled and completed as soon as possible in the project in order to trouble shoot any issues
  - Free Standing
    - More useful on complicated buildings and details, but hard to get done as a performance mock up that is able to be tested.

This should be indicated in the project specifications

Field Testing

- What is considered a fail?

- AAMA 502 – per ASTM E1105 – no water passing the interior parallel plane.
- AAMA 503 – not more than 0.5oz during the 15 minute test and not passing the interior parallel plane.

Field Testing

- Who pays for the retest?

- AAMA 502 – should be listed in the Specifications
- AAMA 503 – no mention

Should be the party that is responsible for the failure

Physics of Testing

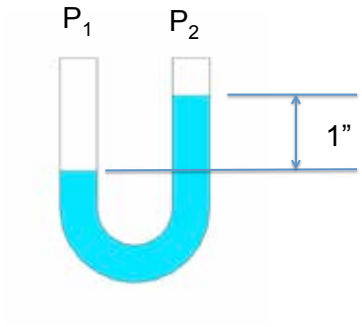
P_1 = 0 in H_20

P_2 = 0 in H_20

Physics of Testing

P_1 = 1 in H_20

P_2 = 0 in H_20



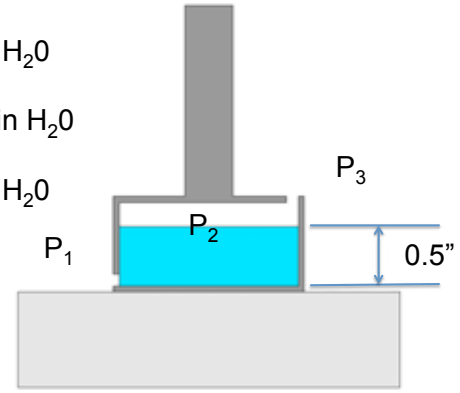
Physics of Testing

Physics of Testing

P_1 = 1 in H_20

P_2 = 0.5 in H_20

P_3 = 0 in H_20



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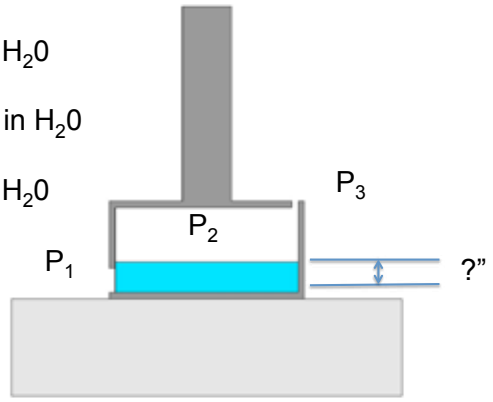
Physics of Testing

P_1 = 1 in H_20

P_2 = ??? in H_20

P_3 = 0 in H_20



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Physics of Test

- Methods of Water Transport
- Friction (air drag)
- Pressure on a film

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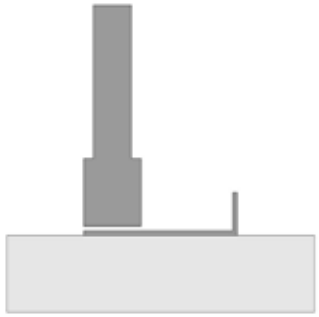
Physics of Test

- The “Slider” Example



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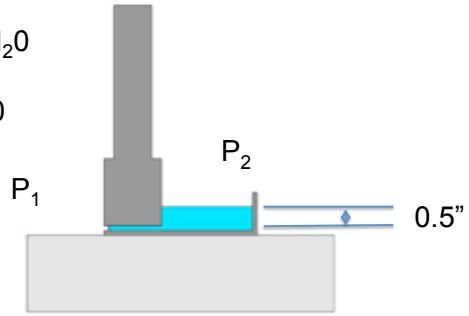
Physics of Test

- The “Slider” Example

P_1 = 0.5 in H_20

P_2 = 0 in H_20



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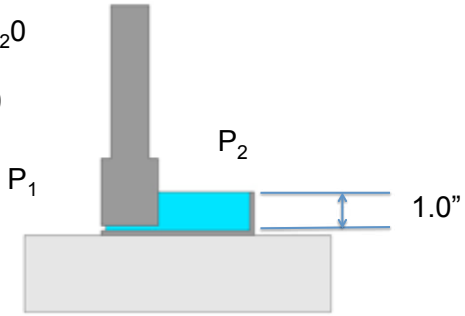
Physics of Test

- The “Slider” Example

P_1 = 1.0 in H_20

P_3 = 0 in H_20



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Test Set Up

- Chambers
  - Not permitted to touch the frame
  - Must be air tight enough to get to the negative pressure
- Spray Rack
  - Calibrated to a certain water pressure
  - Need to have adequate water pressure
- Set up and TEST EVERYTHING the day before the scheduled testing

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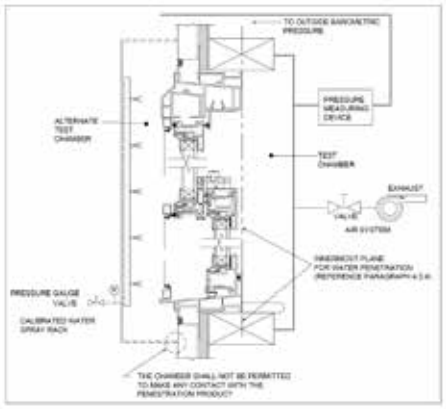
Test Set Up



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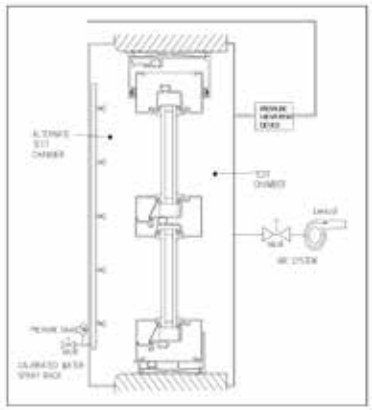
Test Set Up



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Test Set Up

- Procedure
- Method A – 15min static test - for AW Windows, Storefront, Curtain Walls, Skylights
- Method B – 5 minute static cyclical test (4 cycles typically) for all other windows

Window Failures

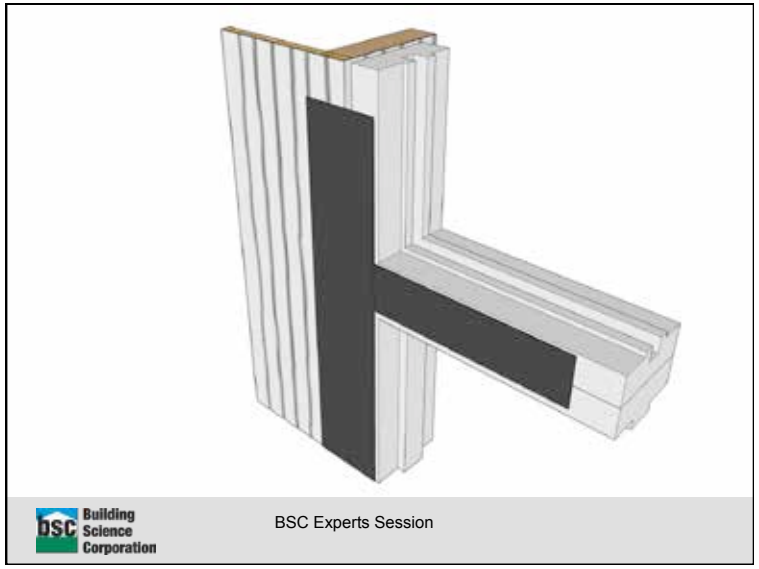
- What is the most common failure?

The Windows

The Doors

Window/Door Failures

- What is the most common failure?
  - Corner welds
  - Corner seals
  - Mulled joints
  - Meeting rails
  - Glazing seals
  - Glazing units
  - Hardware
  - Screw fasteners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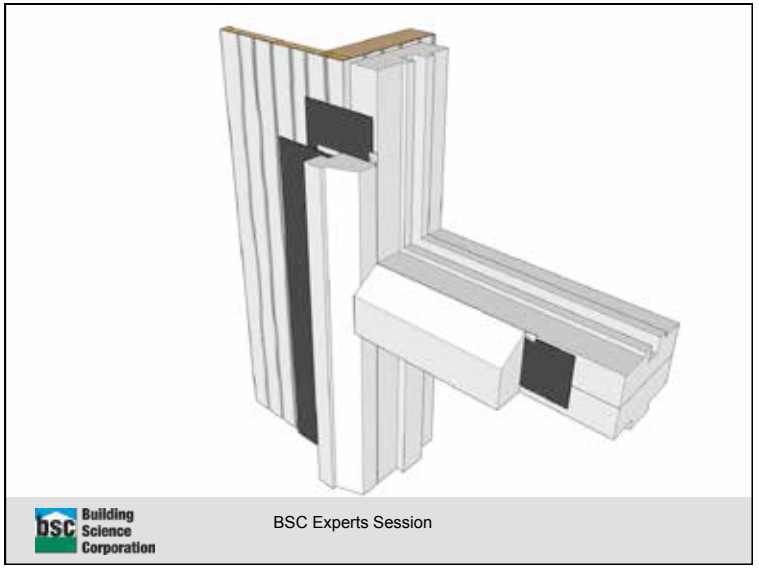
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aightFlash


LOW-E
GLASS


10/29/2013 14:01


10/16/2013 11:12


10/16/2013 11:14

Windows/Doors

- Physics/Strategies
  - Gravity
  - Pressure Moderation (Two-stage joints)
  - Three seals
    - Primary
    - Interior
    - Exterior
  - Pan flashed and drained openings
  - Dealing the window industry (they are a force unto themselves)

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Windows/Doors

- Window Seals
  - Recommend Three Seal Locations
    - Primary – integrated with the wall water control layer
    - Interior – interior air seal for pressure moderation
    - Exterior – weather/aesthetic seal at the window to cladding interface

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Windows/Doors

- Window Seals
  - For flanged windows the primary seal is made be taping the flanged to the wall WRB
  - For non-flanged windows, the primary seal will either be:
    - A backer rod and sealant joint
    - A membrane flange adhered directly to the window frame and WRB.
  - Interior Seal is typically a backer rod and sealant joint or a bead of low expansion foam
  - Exterior is typically a backer rod and sealant joint

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Windows/Doors

- Window Installation
  - Three general types
    - Flush with WRB
    - Recessed opening
    - Bucked out opening
  - Flush with WRB is easiest, lowest cost and least risky

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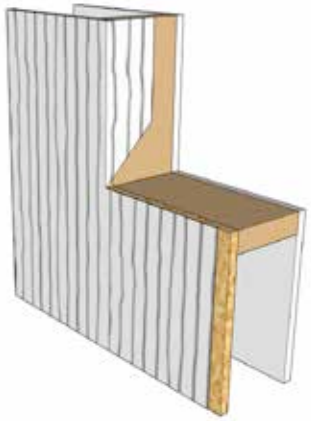
Windows/Doors



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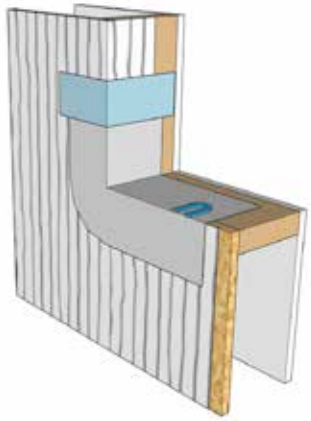

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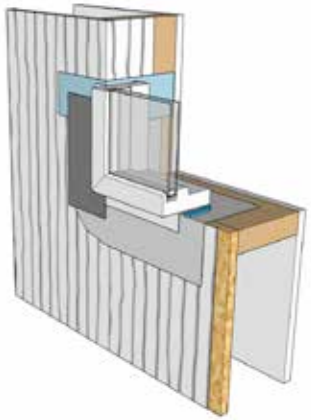

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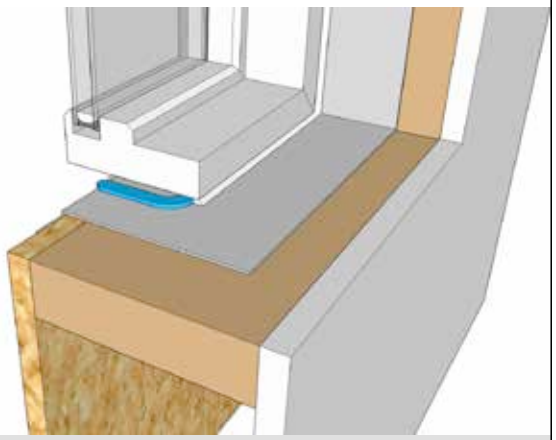

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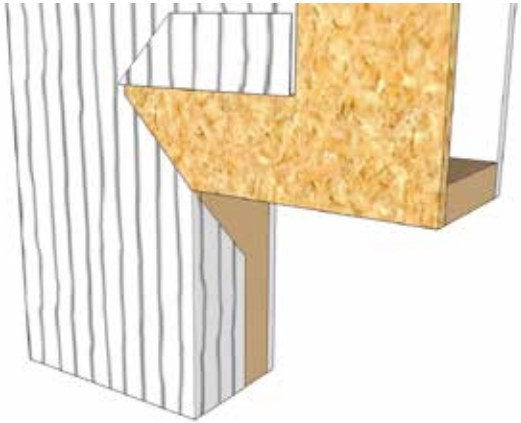

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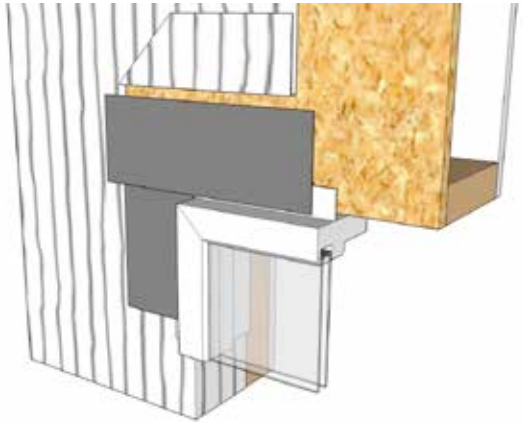
Windows/Doors



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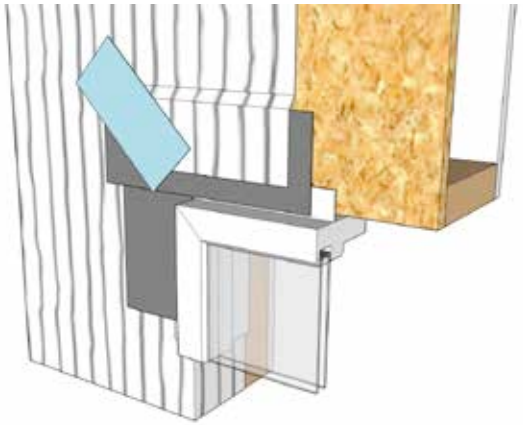

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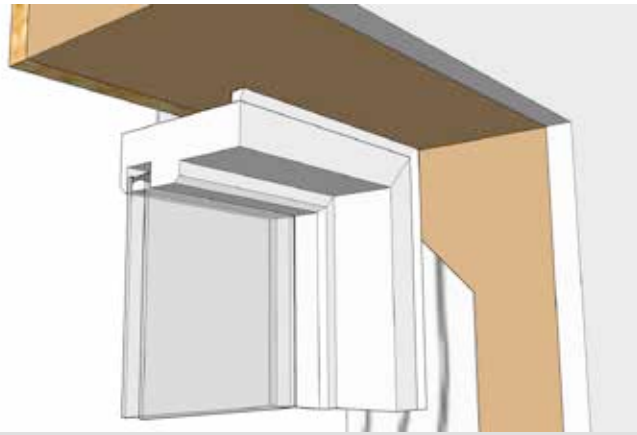

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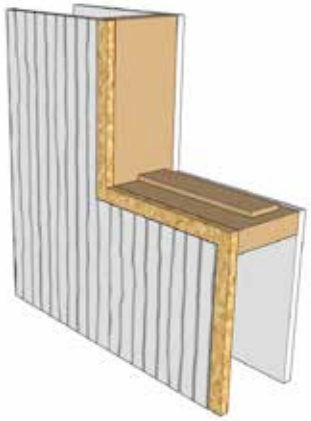

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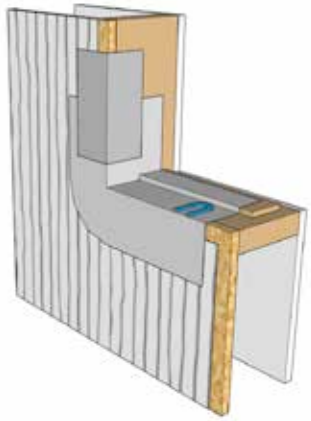

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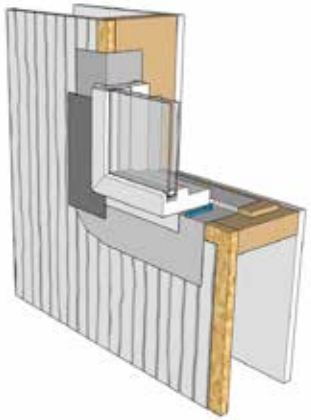

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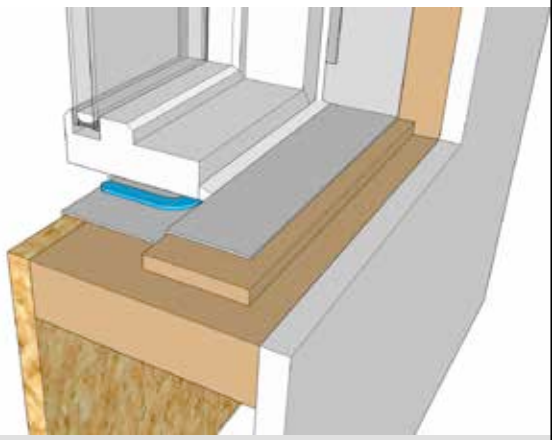

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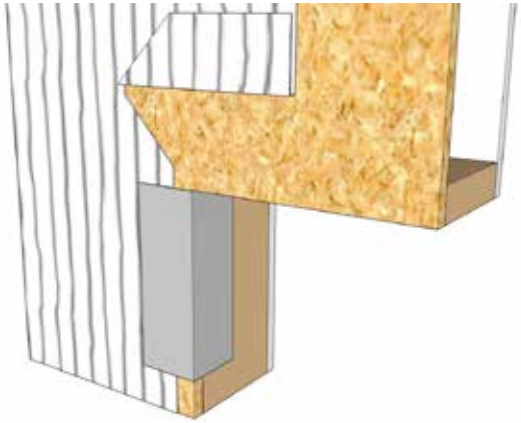

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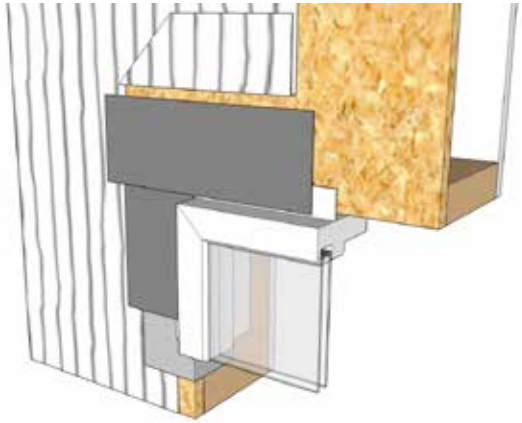

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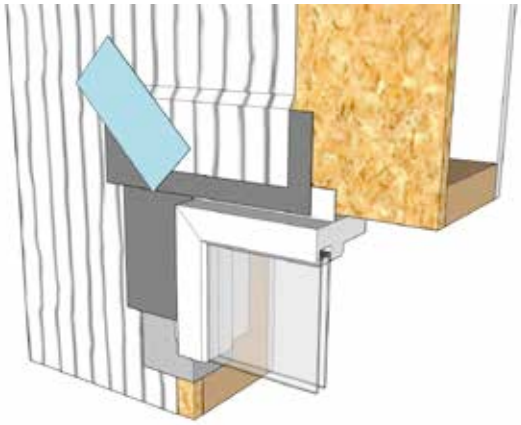

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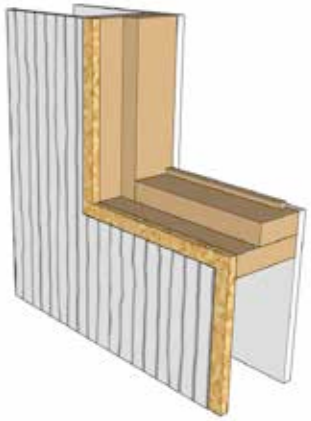

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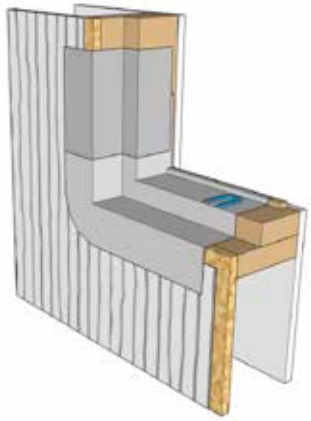

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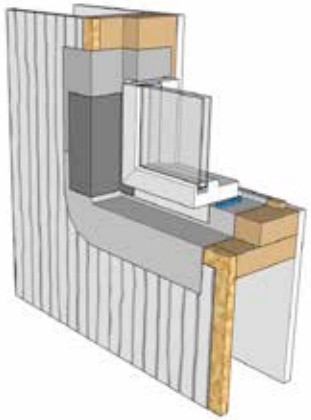

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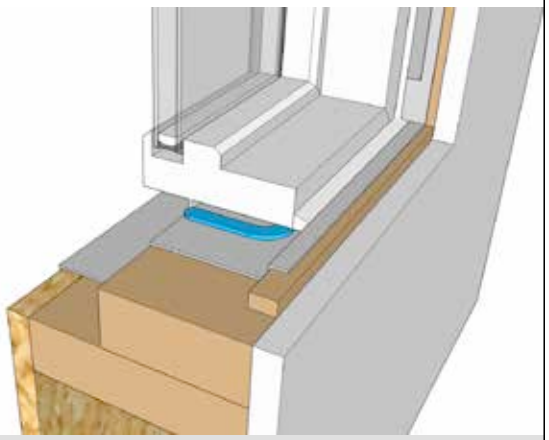

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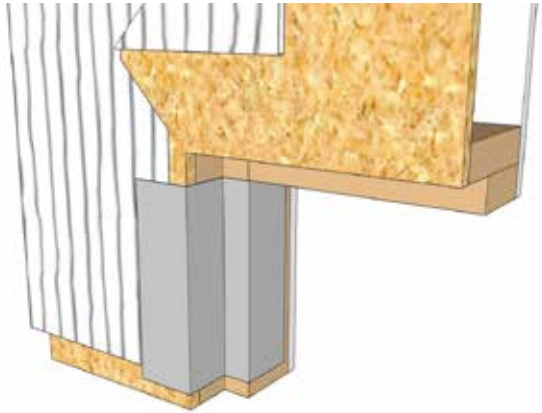

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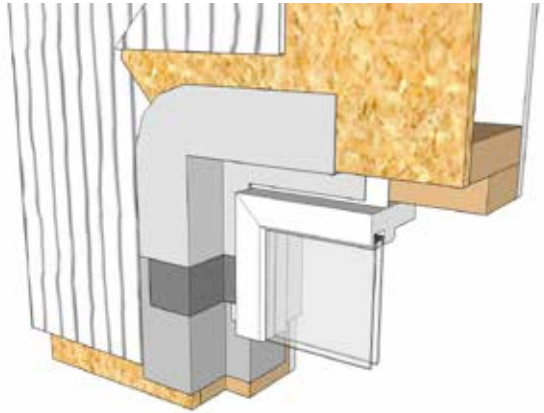

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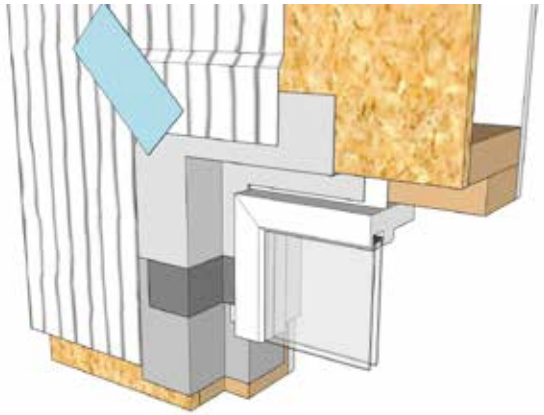

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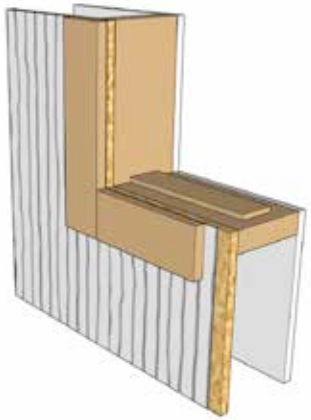

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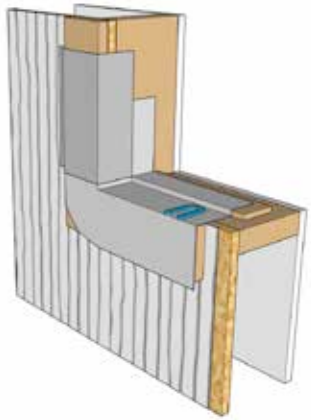

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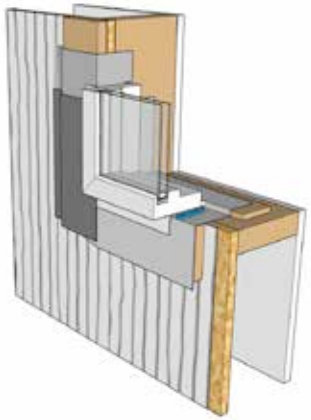

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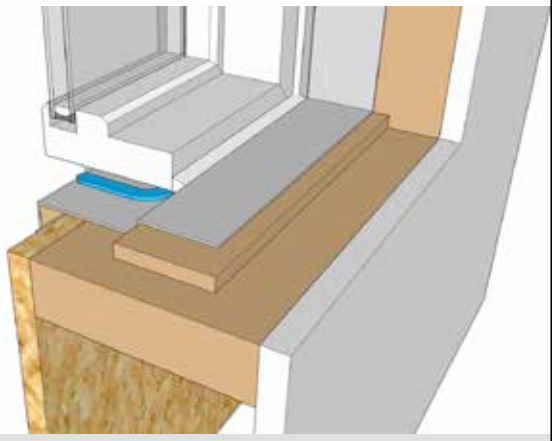

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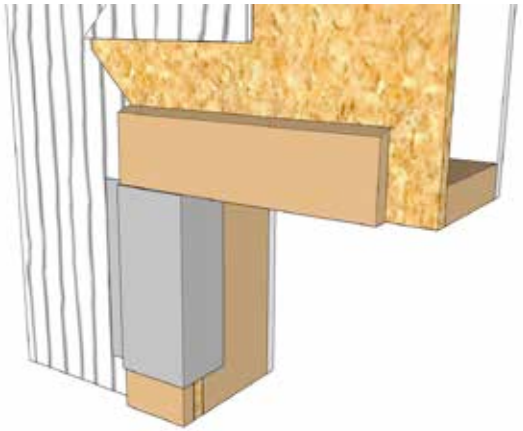

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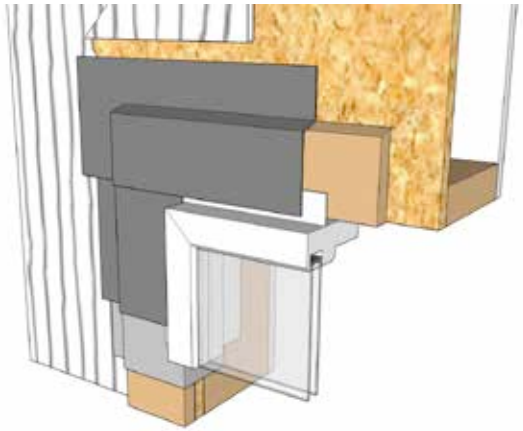

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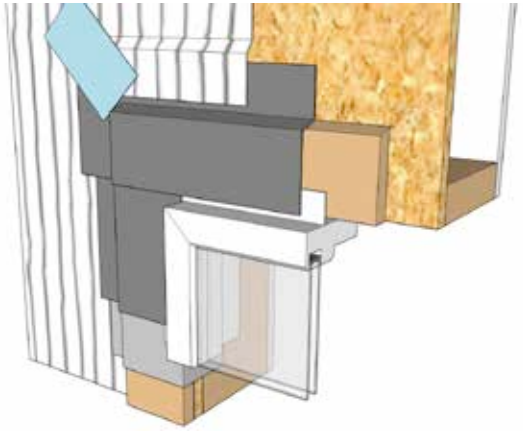

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  - Three seals are ideal (usually only two is achievable)
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Questions?

Peter Baker, P. Eng.
pbaker@buildingscience.com

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